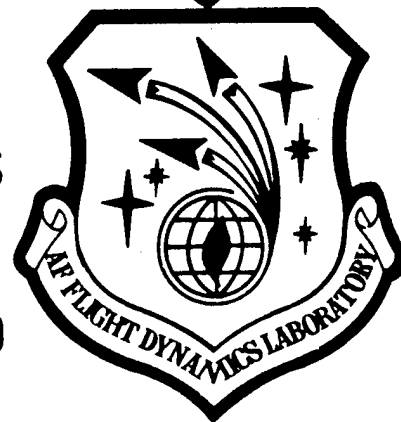


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**AIR FORCE FLIGHT DYNAMICS LABORATORY  
DIRECTOR OF LABORATORIES  
AIR FORCE SYSTEMS COMMAND  
WRIGHT PATTERSON AIR FORCE BASE OHIO**



A PORTABLE OXIDES OF NITROGEN ANALYZER FOR ELECTRIC  
ARC HEATED GASDYNAMICS TEST FACILITIES

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EXPERIMENTAL ENGINEERING BRANCH  
FLIGHT MECHANICS DIVISION

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## FOREWARD

One of the characteristics of electric arc heated gasdynamics test facilities is that oxides of nitrogen are formed in their effluent. A portable oxides of nitrogen gas analyzer was developed by the Air Force Flight Dynamics Laboratory to measure the concentrations of these pollutants as a first step in a program to reduce or eliminate them.

This Technical Memorandum has been reviewed and is approved.



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PHILIP P. ANTONATOS  
Chief, Flight Mechanics Division  
Air Force Flight Dynamics Laboratory

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## SUMMARY

This Technical Memorandum describes a portable oxides of nitrogen gas analyzer designed and built by the Air Force Flight Dynamics Laboratory (AFFDL). This unit incorporates commercial gas analysis instruments which are capable of detecting both nitrogen dioxide and nitric oxide in concentrations of from 0 - 5000 ppm and 0 - 50000 ppm to an accuracy of 1% of full scale range. All the components necessary for on-site operation are incorporated into the analyzer and it is rugged enough to be moved from one location to another without impairing its reliability. The analyzer is presently being used to measure  $\text{NO}_x$  concentrations in the exhaust from the AFFDL 50 Megawatt Hypersonic Test Leg (HTL) arc heated gasdynamic test facility.

## INTRODUCTION

A portable oxides of nitrogen gas analyzer system has been specially designed by AFFDL engineers for use in on-line exhaust gas measurements in the Air Force Flight Dynamics Laboratory 4 Megawatt and 50 Megawatt HTL Electrogas dynamics Test Facilities. The analyzer system is capable of detecting nitrogen dioxide ( $\text{NO}_2$ ) and nitric oxide ( $\text{NO}$ ) in concentrations of from 0 - 5000 ppm and 0 - 50000 ppm by means of dual series sample cells, with an accuracy of 1% of full scale range.

One of the characteristics of electric arc heated gas dynamics test facilities is that oxides of nitrogen ( $\text{NO}_x$ ) are formed in the effluent. The extremely high temperatures resulting from heating the air when it is passed through the electric arc causes dissociation into nitrogen and oxygen ions. As high as 5% of this air is converted into oxides of nitrogen when it recombines. When this effluent is exhausted, pollution of the atmosphere would result if no preventive actions were taken.

In order to design suitable anti-pollution apparatus the concentrations of the noxious  $\text{NO}_x$  fumes generated by various facility operating modes must be determined. An analytical determination of the chemical reactions which take place in the facility is a very complex undertaking, and while the methodology might prove extremely interesting to the academician, the results would be no more useful than those which can be gained by effective sampling and measuring, given the proper instrumentation and operating techniques.

This report will then deal with the design criteria, the operating techniques and a detailed description of the portable  $\text{NO}_x$  gas analyzer system which was developed expressly for measuring  $\text{NO}_x$  concentrations in the AFFDL electric arc heated gas dynamics facility exhausts.

## DESIGN CRITERIA

Based on operating experience in the two AFFDL electric arc heated test facilities the following design criteria was established.

The system was designed to be portable and essentially self contained. The two facilities to be serviced are located in different buildings approximately a half mile apart and from the economic stand point it was more practical to build a portable system which could be moved between the buildings than to purchase and install an independent system for each facility.

The instruments which constitute the core of the system, an ultraviolet (UV) analyzer for  $\text{NO}_2$  and an infrared (IR) analyzer for  $\text{NO}$ , were selected after a review of the instruments commercially available. The availability of competent electronic and mechanical technicians and the lack of trained chemical technicians or a chemistry laboratory weighed heavily in the choice of the UV and IR analyzers over standard wet chemistry techniques. The supporting appurtenances required by the electronic analyzers were considered to be more suitable for portability than those required by wet chemistry techniques. For example, a purge system, for cleaning all of the lines in the gas analyzer system is completely built into the cart; a calibration system for either analyzer requires only plugging a certified calibration gas into the system through an external patch panel and arranging the internal circuits.

The portable gas analyzer system was designed for on-line sampling so that variations in concentrations can be correlated with changes in facility operations. Sampling apparatus and techniques were developed in order to minimize any errors which might result from sampling time lags, temperature changes and background interferences.



The external patch panel was incorporated in the design in order to simplify and accelerate changes in sampling source, and equipment configuration.

## SYSTEM DESCRIPTIONS

The oxides of nitrogen gas analyzer, as shown in Figure 1, is contained in an enclosed cabinet mounted on wheels. It incorporates a Beckman Instrument Company, Model 255, Ultraviolet Nitrogen Dioxide analyzer, Reference 1; a Beckman Instrument Company Model 315A Infrared Nitric Oxide analyzer, Reference 2; a calibration system; a sampling system; internal manifolding with pump; and an external patch panel.

GAS ANALYZERS: The NO<sub>2</sub> analyzer is an ultraviolet filter photometer employing a simple optical principle to continuously measure the concentrations of gaseous samples which exhibit absorption characteristics in the near ultraviolet energy range. The analysis is based on a differential measurement of the absorption of ultraviolet energy between the sample cell and a reference cell. A simplified functional diagram is shown in Figure 2.

The NO infrared analyzer incorporates a similar optical system which measures the amount of infrared energy absorbed by the NO in the sample on a continuous basis. Infrared radiation, passing through the sample cell, is absorbed by the NO. The percent of radiation absorbed is proportional to the concentration of the NO in the sample. A simplified functional diagram is shown in Figure 3.

The Beckman Instrument Company specifications for the instruments are as follows:

Range - 0 to 5% and 0 to 5000 ppm by means of dual series sample cells.  
Accuracy - 1% of full scale range.  
Response - 90% in 0.5 second, exclusive of cell flushing.  
Ambient Temperature Range - 40° to 120°F.  
Output - Indicating meter and potentiometric recorder output of 0-1000 millivolts.  
Zero Drift - Less than 1% in 8 hours.  
Span Drift - Less than 1% in 24 hours.

Operating experience has shown that to obtain the accuracy and response specified, the cells and all of the interconnecting manifolding must be thoroughly flushed with a nitrogen purge gas and consequently extreme care must be taken to eliminate any potential gas pockets or traps which might complicate the purge cycle. The response time of the system is considerably in excess of the instrument specifications, approaching two to three minutes for stable readings. This is probably a function of the complexity of the internal manifolding and the length of the sampling lines.

CALIBRATION: The analyzer system incorporates provisions in the patch panel for the calibration of each cell of each analyzer independently or simultaneously, in series or parallel. The calibration is made with known concentrations of NO<sub>2</sub> and NO certified by a gas manufacturer. The gases used to calibrate this analyzer are as follows:

- a. 4.9% maximum nitric oxide, balance nitrogen.
- b. 0.49% maximum nitric oxide, balance nitrogen.
- c. 4.9% maximum nitrogen dioxide, balance nitrogen.
- d. 0.49% maximum nitrogen dioxide, balance nitrogen.
- e. .049% maximum nitrogen dioxide, balance nitrogen.

The UV and IR instruments have a multiple range sensitivity control so that the scale span can be optimized for samples in a broad range of concentrations. During the preliminary shakedown of the analyzer system it became apparent that the two ranges furnished were not optimum for the NO<sub>x</sub> concentrations measured in the 50 Megawatt HTL Facility effluent.

Effluent samples taken before and after scrubbing suggested that the 0 - 0.5% range is too low for the unscrubbed inlet and too high for the scrubbed

exit concentrations. With exit concentrations of approximately 0.04% the instrument accuracy, 1% of full scale reading, is greater than 12% of the sample concentration.

The 0 - 5% range was similarly unsatisfactory because the high electronic gain required to use the short (0 - 5%) cell alone caused a zero shift of as much as  $\pm 4\%$  of full scale. With inlet samples of approximately 2% this shift represents  $\pm 15\%$  of the sample concentrations.

In order to reduce these errors the instruments have been calibrated using the long (0 - 0.5%) cell where possible to minimize the gain required. Since there are three control ranges available, they have been adjusted so that the full scale meter reading on Range II corresponds to half that of Range I and Range III corresponds to half that of Range II.

Calibration procedures for both instruments have been developed for the 0 - .5%, 0 - 1% and 0 - 2% ranges using the 0.49% NO and NO<sub>2</sub> calibration gases and for the UV instrument, the 0 - 0.2%, 0 - 0.4% and 0 - 0.8% ranges using the 0.049% NO<sub>2</sub> calibration gas. Calibration checks were made using both concentrations of the calibration gases and by diluting calibration gas with nitrogen for mid scale checks.

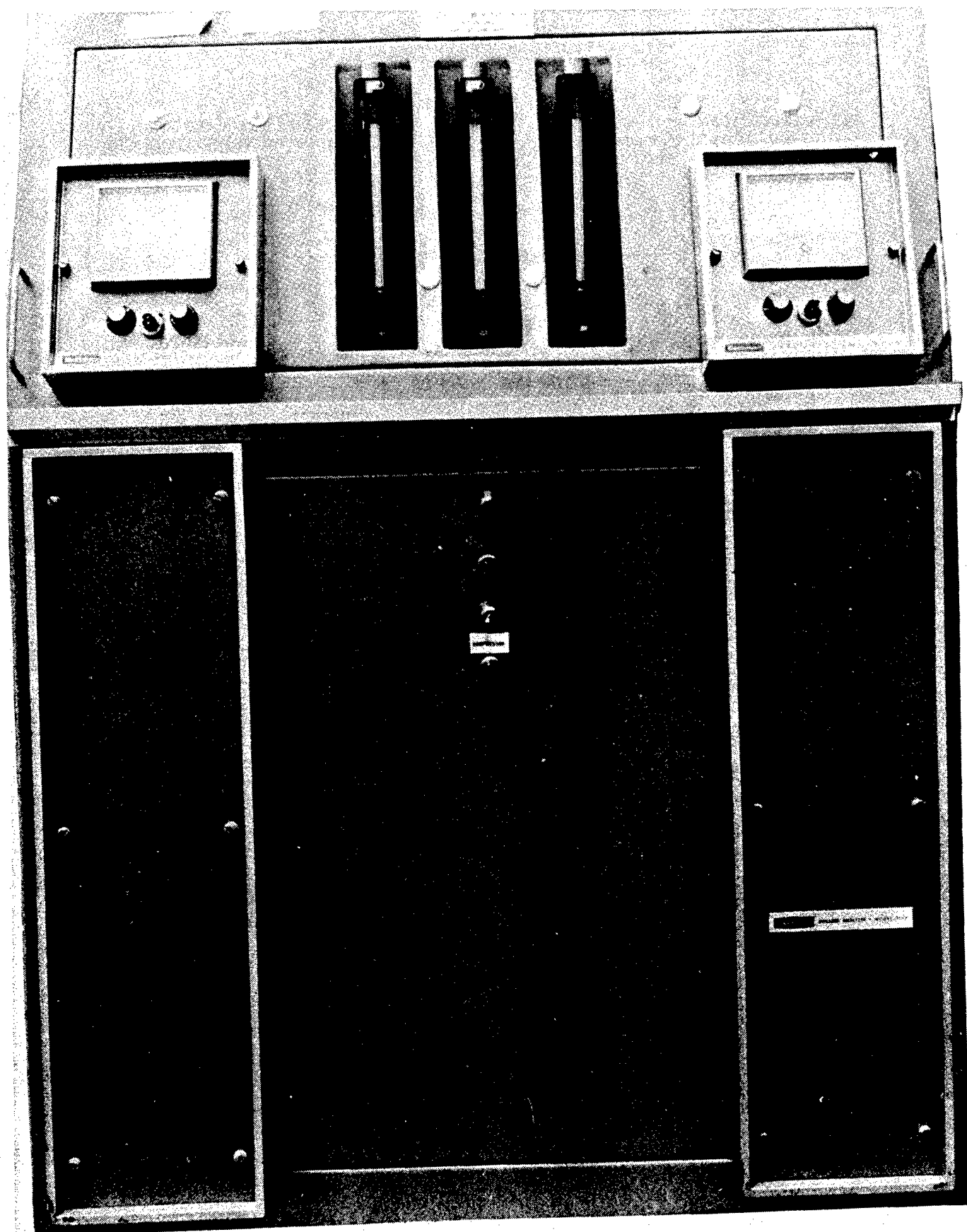
EXTERNAL PATCH PANEL: The key to the flexibility of the gas analyzer system is the external patch panel, Figure 4. Each component in the cart is independently connected to the patch panel as shown schematically in Figure 5. The patch panel terminals are pressure-tight couplings which permit unrestricted flow in either direction when connected and which instantly cut off flow when disconnected. The patch panel jumpers are stabilized polypropylene tubing made up in a series of lengths, fitted with quick disconnect couplings.

PAGES 8 & 9

ARE  
MISSING  
IN  
ORIGINAL  
DOCUMENT

## FUTURE DEVELOPMENTS

Currently the portable analyzer is used to monitor the effluent from the AFFDL 50 Megawatt HTL Facility in order to evaluate the results of experiments aimed at reducing the concentrations of NO<sub>x</sub> the facility exhausts to the atmosphere. As noted under the description of the gas sampling system the NO<sub>x</sub> concentrations are read on meters, corrected according to calibration curves and then hand recorded. During the orderly development of the NO<sub>x</sub> emission control program, analyzer output signals will be fed to data recorders and eventually used to control an automatic emission control system.



PORTABLE GAS ANALYZER

Figure 1

B. REFERENCE BEAM BLOCKED, SAMPLE BEAM NOT BLOCKED BY CHOPPER, PASSES THRU SAMPLE CELL TO DETECTOR





A. BEAMS NOT BLOCKED BY CHOPPER PASS THRU CELLS & INTO DETECTOR

B. BEAMS BLOCKED BY CHOPPER DO NOT REACH DETECTOR

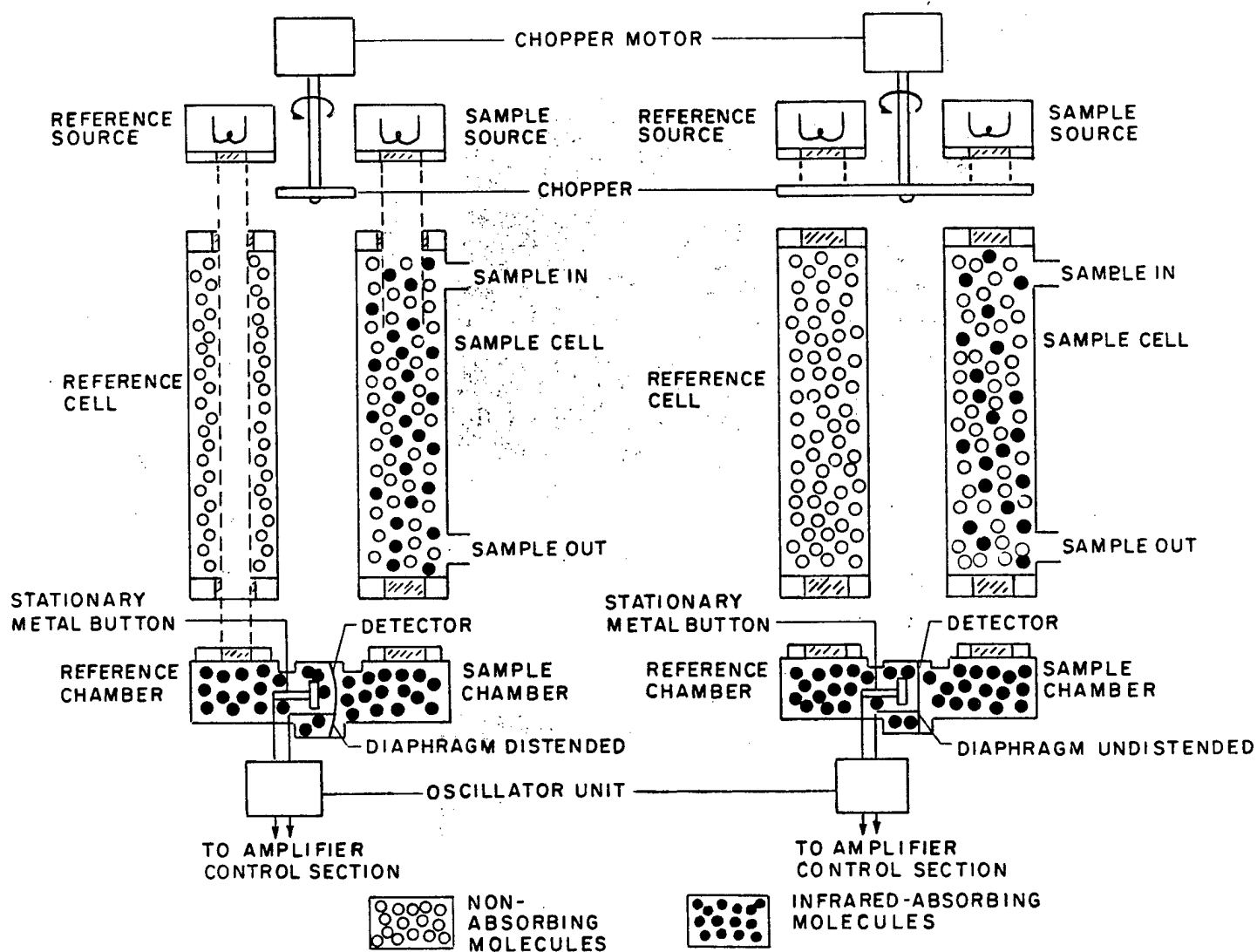
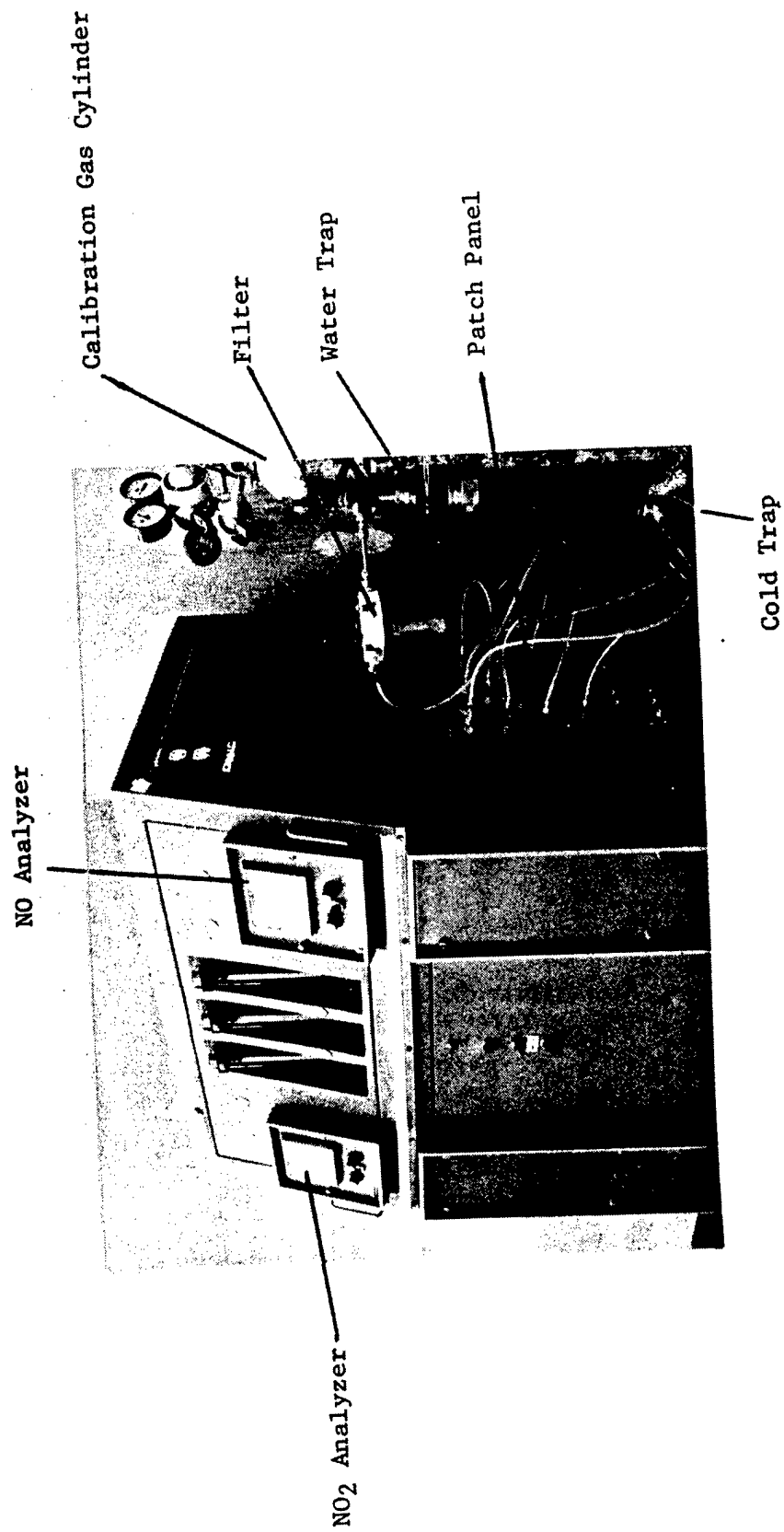


FIG. 3 IR ANALYZER

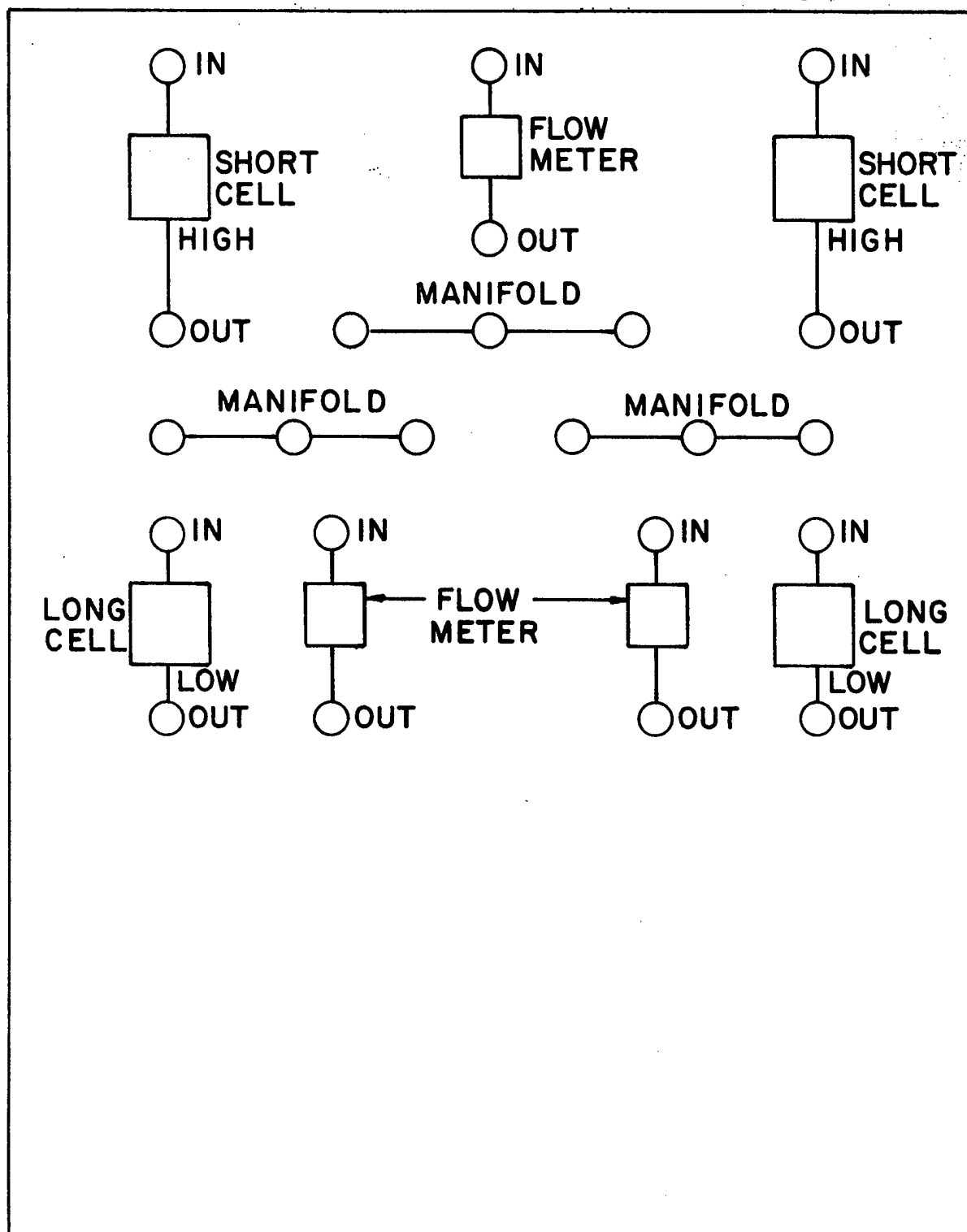


GAS ANALYZER CONNECTIONS

Figure 4

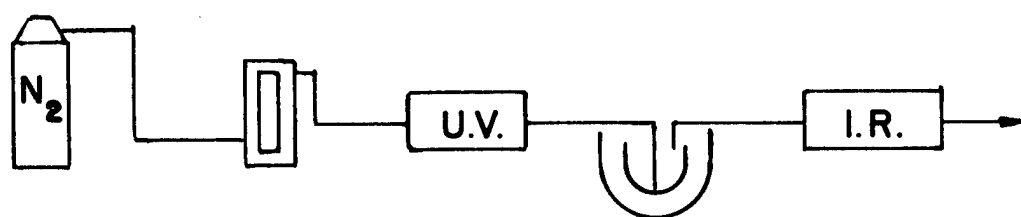
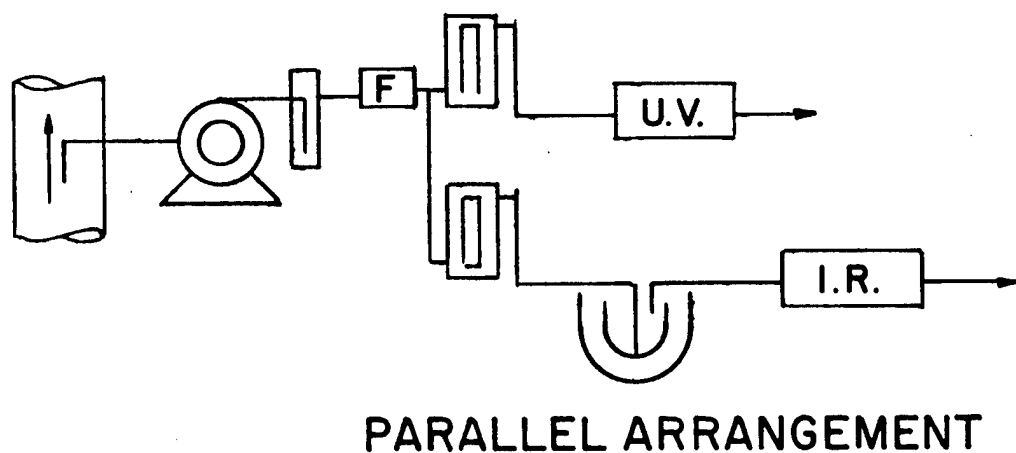
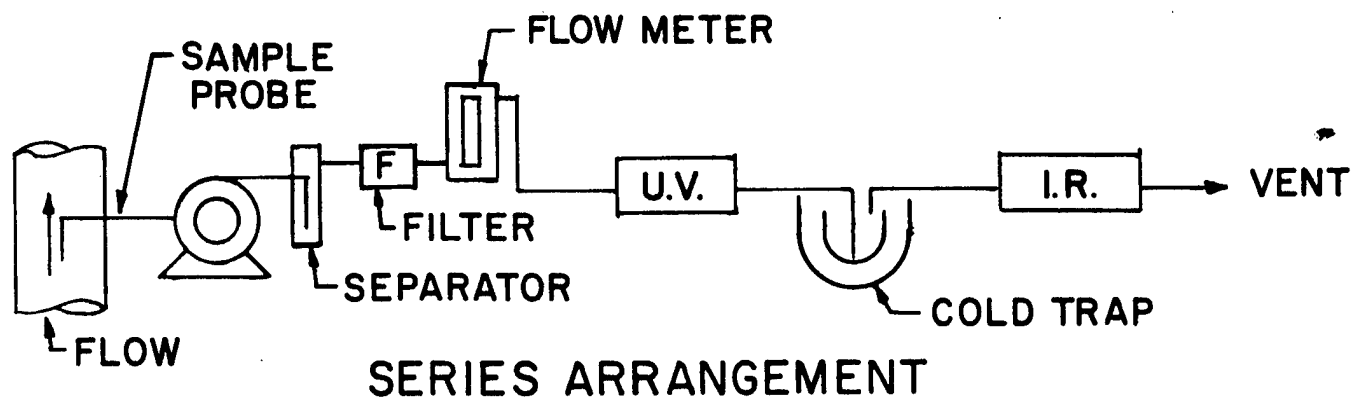
NO  
IR

NO<sub>2</sub>  
UV



EXTERNAL PATCH PANEL

Figure 5



**PURGE ARRANGEMENT**

**Figure 6**

## REFERENCES

1. Beckman Instruction 1707, Model 255A, Ultraviolet Analyzer, Beckman Instrument Company, 1968.
2. Beckman Instruction 1635-B, Model 315A, Infrared Analyzer, Beckman Instrument Company, 1967.